GeoSAR

The GeoSAR Mapping Instrument

by

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JPL

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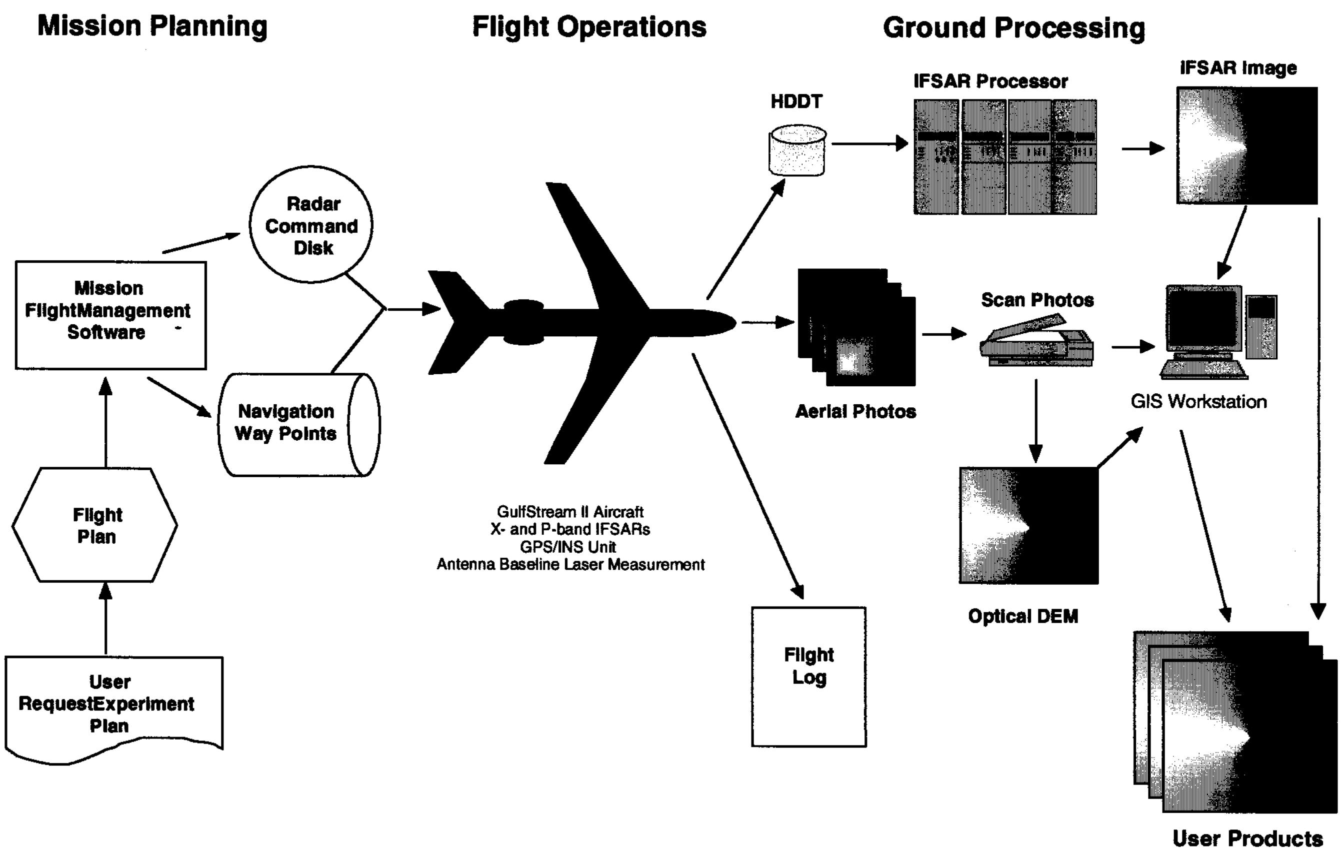
GeoSAR Program

- GeoSAR is a consortium project consisting of JPL, Calgis (a small GIS company based in Fresno, CA) and the California Department of Conservation with funding initially provided by DARPA in November 1996 and now sponsored by NIMA..
- The two main objectives of the GeoSAR Program are
  - to develop a state of the art dual frequency interferometric radar mapping instrument capable of mapping the true ground surface height beneath the vegetation canopy.
  - to transition this mapping technology to a commercial company, Calgis.
- JPL, the technical lead, will deliver at program completion in November of 1999 the following items
  - radar design and radar hardware for X-band (3 cm) and P-band (83 cm) radars
  - processor software, hardware and documentation
  - calibrated X-band radar

Mapping System

- Mapping System Consists of:
  - Aircraft platform to host data collection hardware (Gulfstream II)
  - Flight planning software
  - Dual frequency (X-band/UHF) interferometric SARs
    - Single polarization @ X-band
    - Dual polarization @ UHF
    - Automated radar control
  - Laser interferometric baseline measurement system augmented with embedded GPS/INU systems and differential GPS for precision reconstruction of aircraft flight trajectory and attitude history
  - SAR processors capable of producing DEMs @ X-band and UHF and a true ground surface DEM from combined X-band/UHF analysis
  - A GIS system to analyze digital data

GeoSAR End-to-End System



Processor Elements

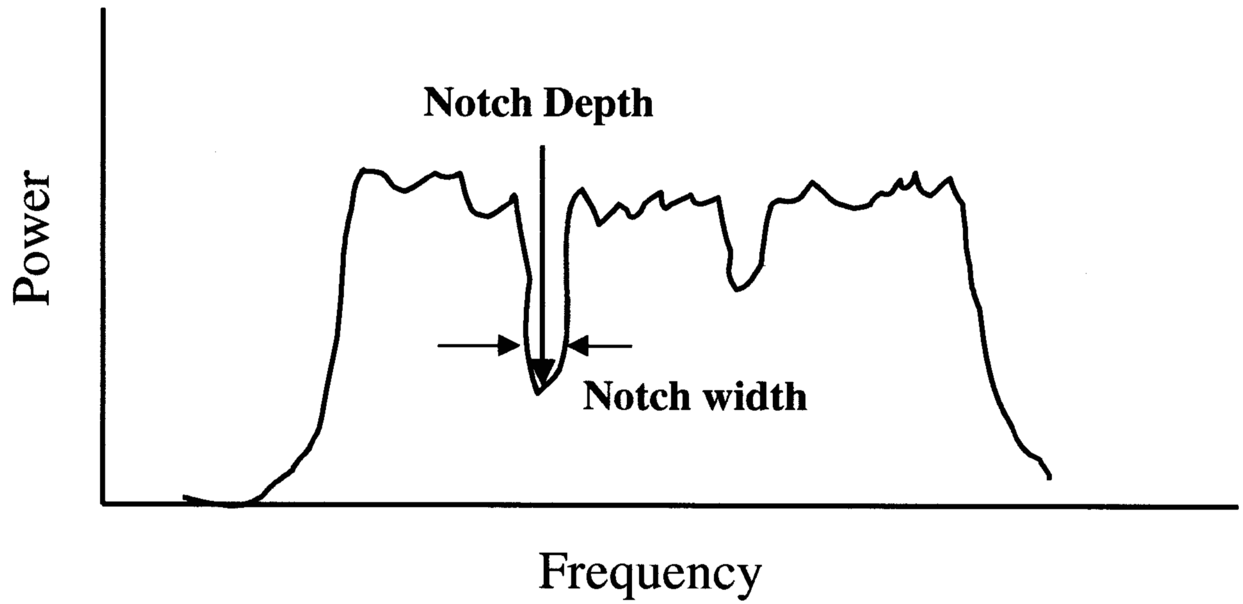
- GeoSAR processor unique elements
  - SAR processors capable of producing DEMs @ X-band and UHF and a true ground surface DEM from combined X-band/UHF analysis
  - Unique focusing and height reconstruction algorithms for P-band
  - Radio Frequency Interference software to remove unwanted interference from radio sources transmitting within the P-band bandwidth
  - True ground surface algorithms using a combination of X-band and P-band data

Hardware Elements

- Unique elements of GeoSAR radar hardware
  - Dual frequency (X-band/UHF) interferometric SARs
    - Single polarization @ X-band
    - Dual polarization @ UHF
    - Automated radar control
    - Automatic waveform generator to generate waveform with notches to avoid interference with sensitive equipment operating in our bandwidth (e.g. glide slope radars).
  - Laser interferometric baseline measurement system augmented with embedded GPS/INU systems and differential GPS for precision reconstruction of aircraft flight trajectory and attitude history.

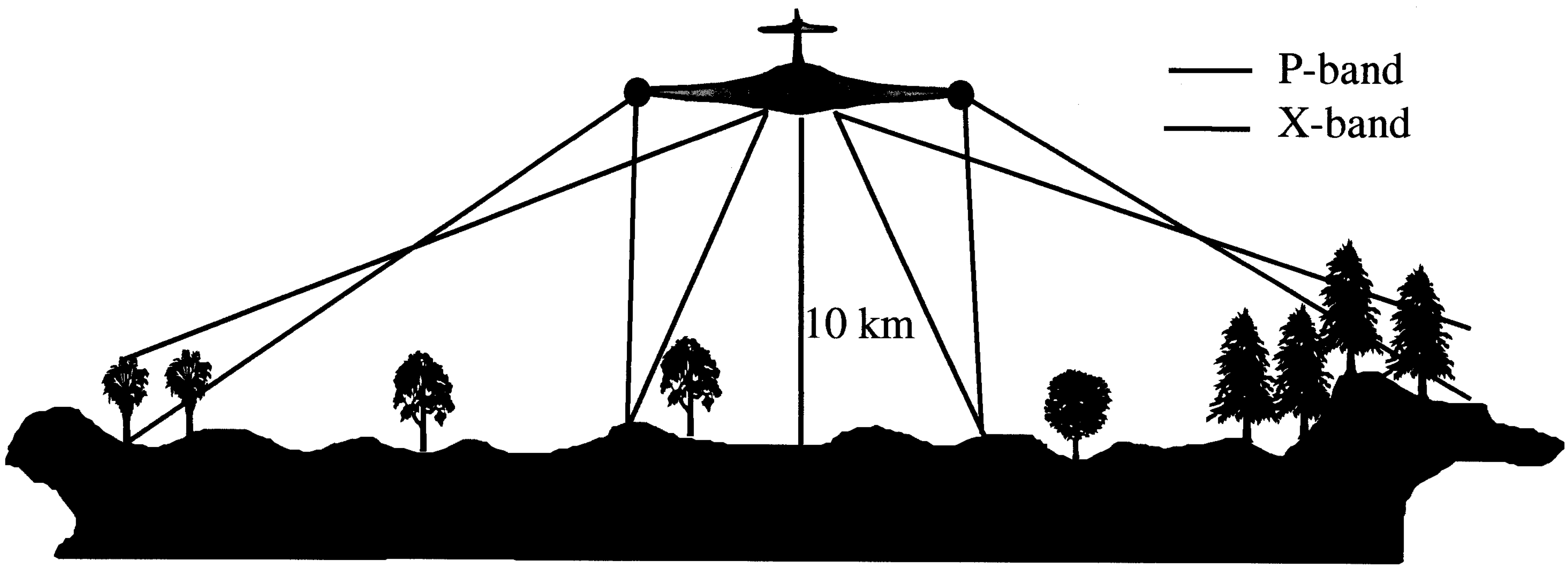
Notching Capability

- Automatic waveform generator to generate waveform with notches to avoid interference with sensitive equipment operating in our bandwidth (e.g. glide slope radars).



Data Collection Basics

- Nominally, GeoSAR will collect X and P-band data from both the left and right sides of the aircraft. Data is recorded on two SONY 512 Mb/s recorders.
- X-band data can be collected using either Ping-Pong or Single Antenna Transmit mode depending on the amount of topographic relief.
- Data can be collected either using 80 or 160 MHz bandwidth modes. Data collected at 160 MHz is converted to 4-bit BFPQ data to reduce the data rate.



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System Parameter Overview

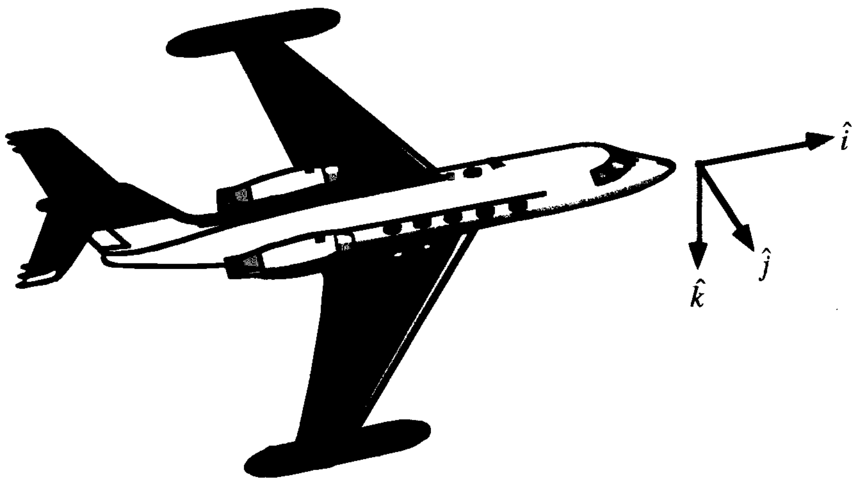
UHF SYSTEM PARAMETERS

Parameter	Value
Peak Transmit Power	4 KW
Bandwidth	80/160 Mhz
Pulse Length	40 µsec
Sampling	8/4 BFPQ @ 160 MHz 8 bit for 80 MHz
Antenna Size	1.524 m x 0.381 m
Antenna Gain at Boresight	11 dBi
Antenna Look Angle	27 - 60 Deg
Antenna Boresight	60 Deg
Wavelength @ Center Frequency	0.86 m for 160 MHz 0.97 m for 80 MHz
Baseline Length	20 m /40 m
Baseline Tilt Angle	0 Deg
Platform Altitude	5000 m - 10000 m
Center Frequency	350 MHz

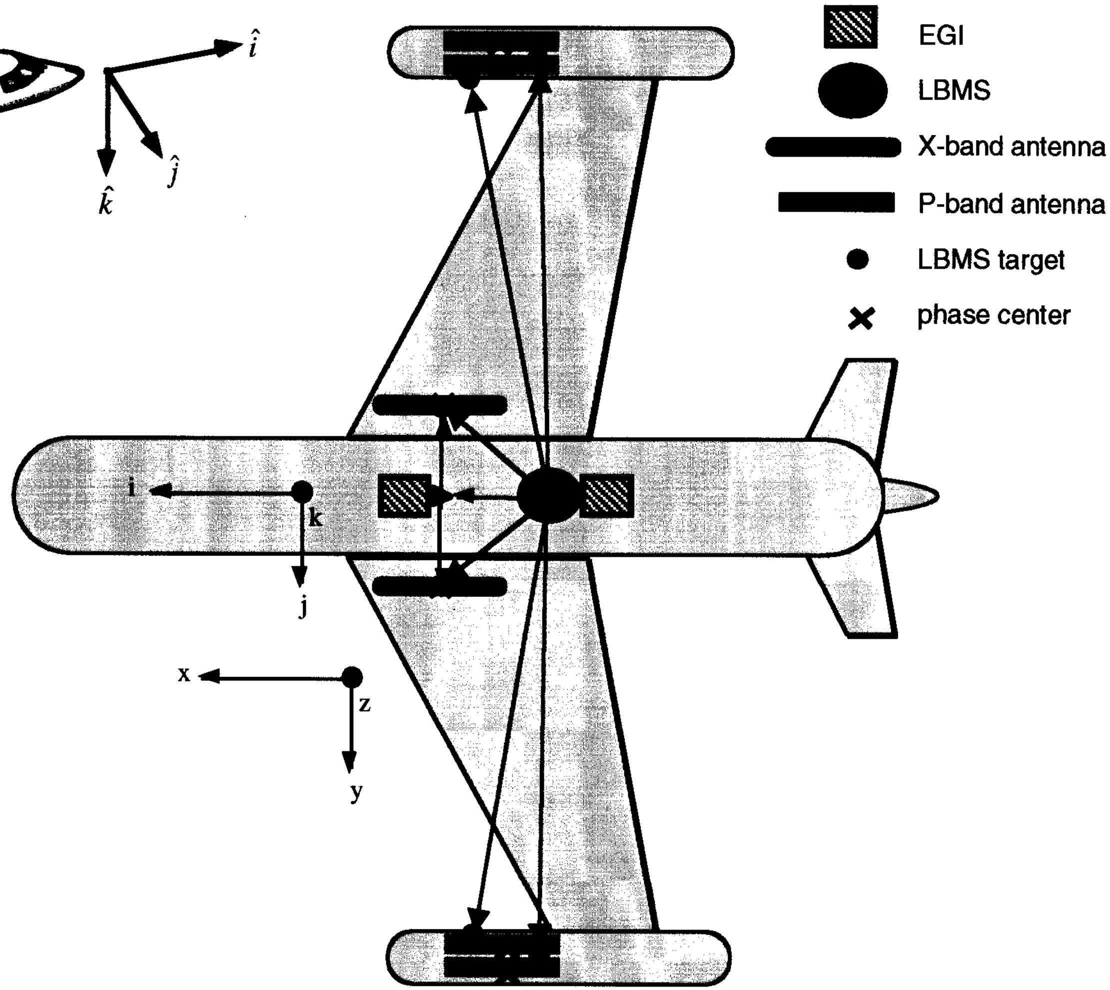
X-BAND SYSTEM PARAMETERS

Parameter	Value
Peak Transmit Power	8 KW
Bandwidth	80/160 Mhz
Pulse Length	40 µsec
Sampling	8/4 BFPQ @ 160 MHz 8 bit for 80 MHz
Antenna Size	1.5 m x 0.035 m
Antenna Gain at Boresight	26.5 dBi
Antenna Look Angle	27 - 60 Deg
Antenna Boresight	60 Deg
Wavelength @ Center Frequency	0.031 m for 160 MHz 0.031 m for 80 MHz
Baseline Length	2.5 m/5 m or 1.3m/ 2.6m
Baseline Tilt Angle	0 Deg or 45 Deg
Platform Altitude	5000 m - 10000 m

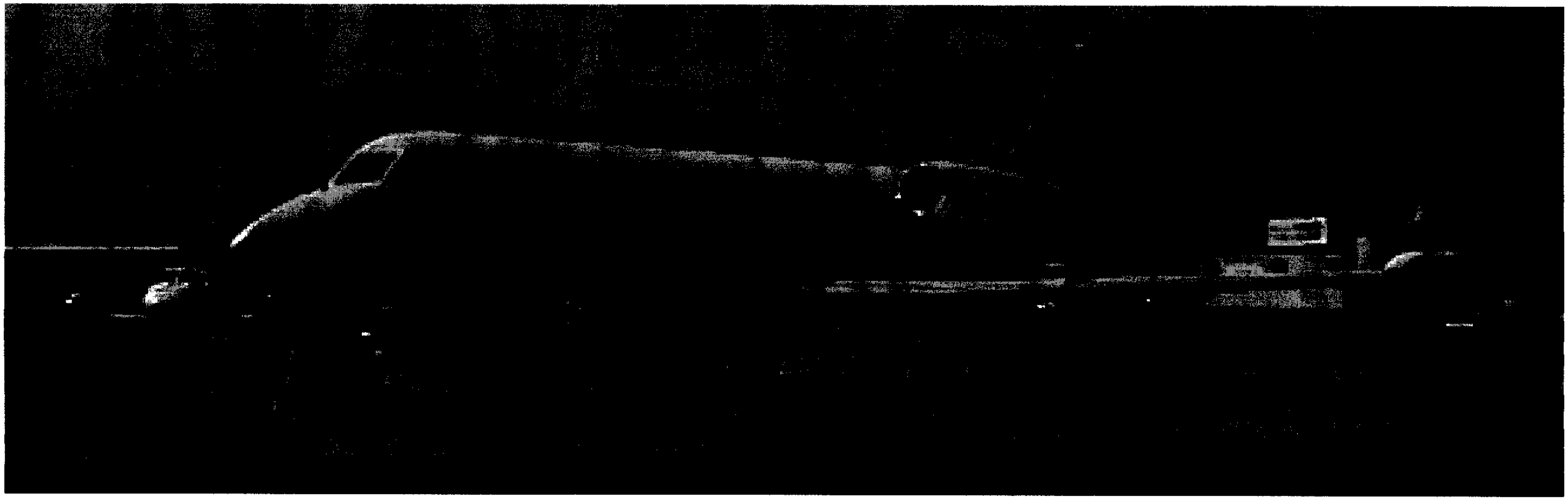
Aircraft System Illustration



Aircraft, bottom view



View of GeoSAR Aircraft Prior To First Flight Test



• Plane is being modified by TAS at the Van Nuys Airport in California.

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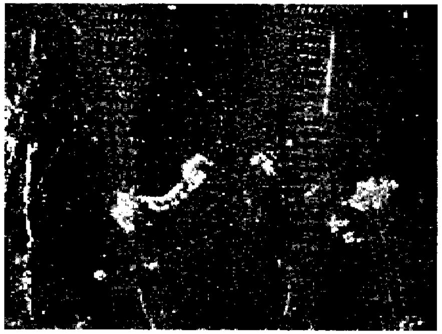
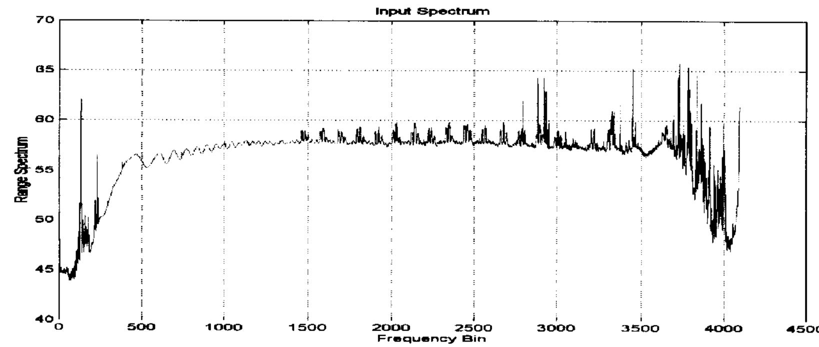
RFI Removal - Sample Inputs



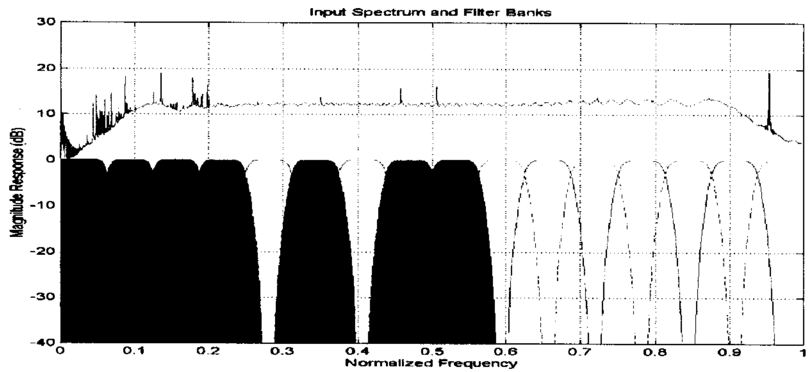
Flat Area

Hilly Area

Range-Doppler Images



One Band



Sub-Bands

Range Spectra

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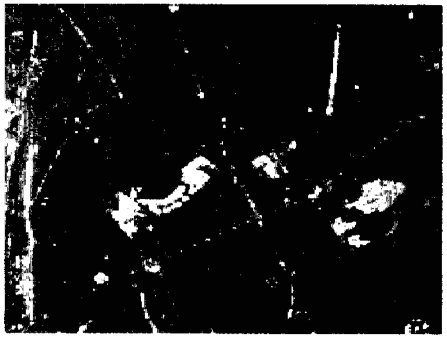
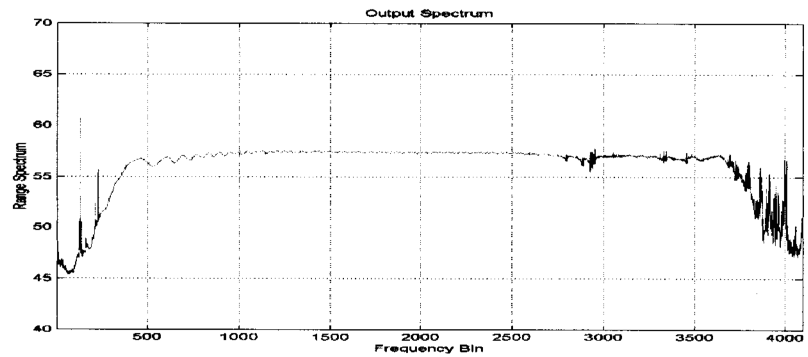
RFI Removal - Sample Outputs

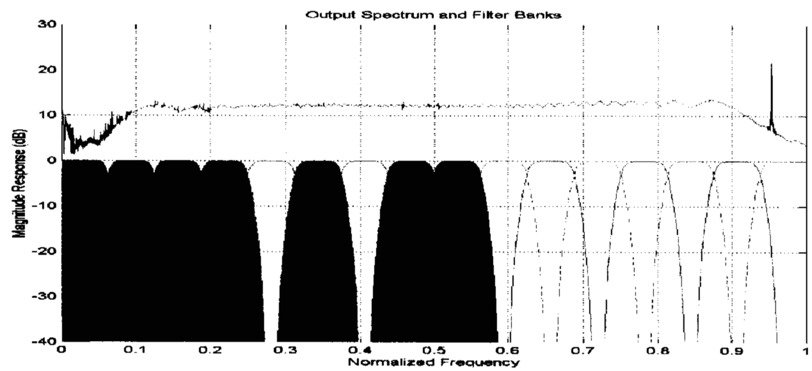


Flat Area

Hilly Area



One Band

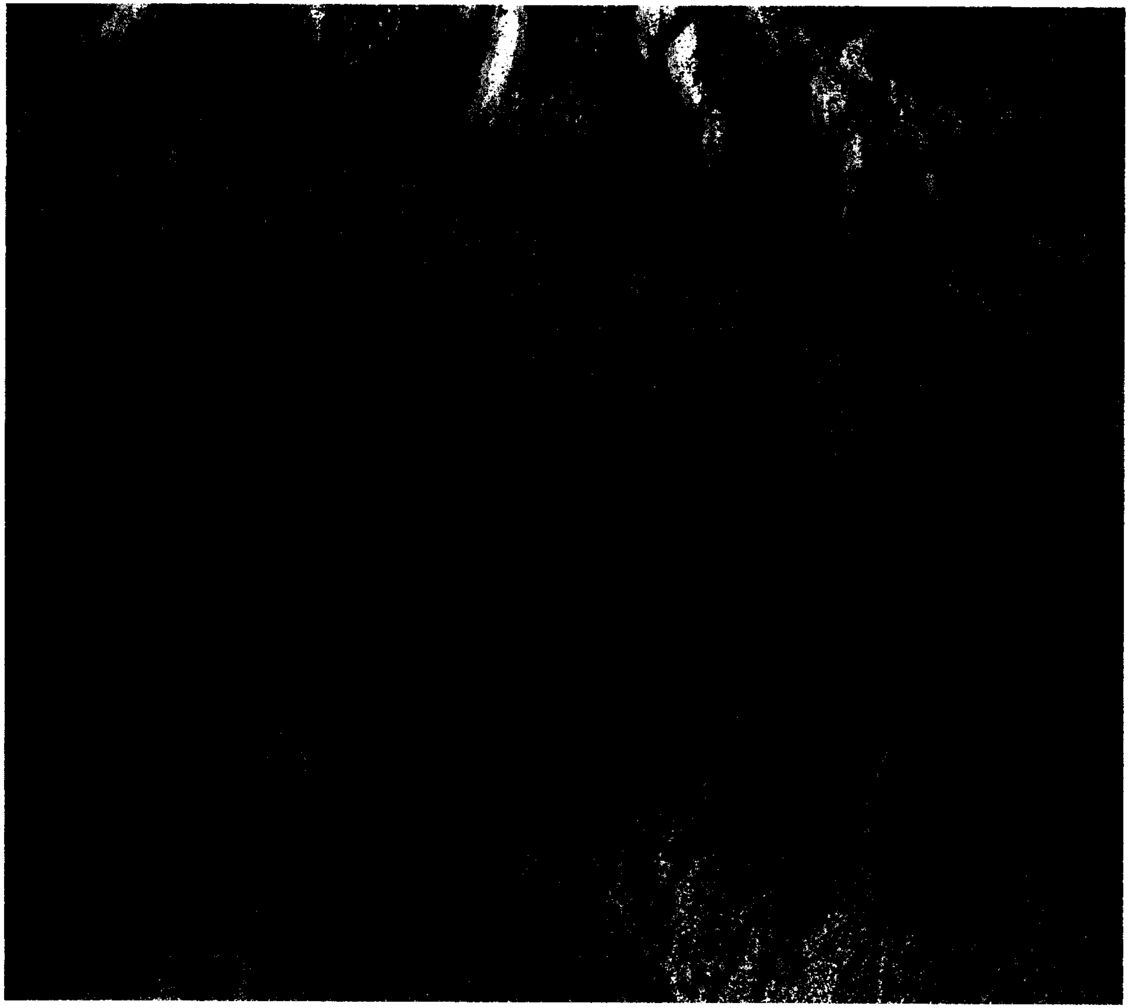


Sub-Bands

Range-Doppler Images

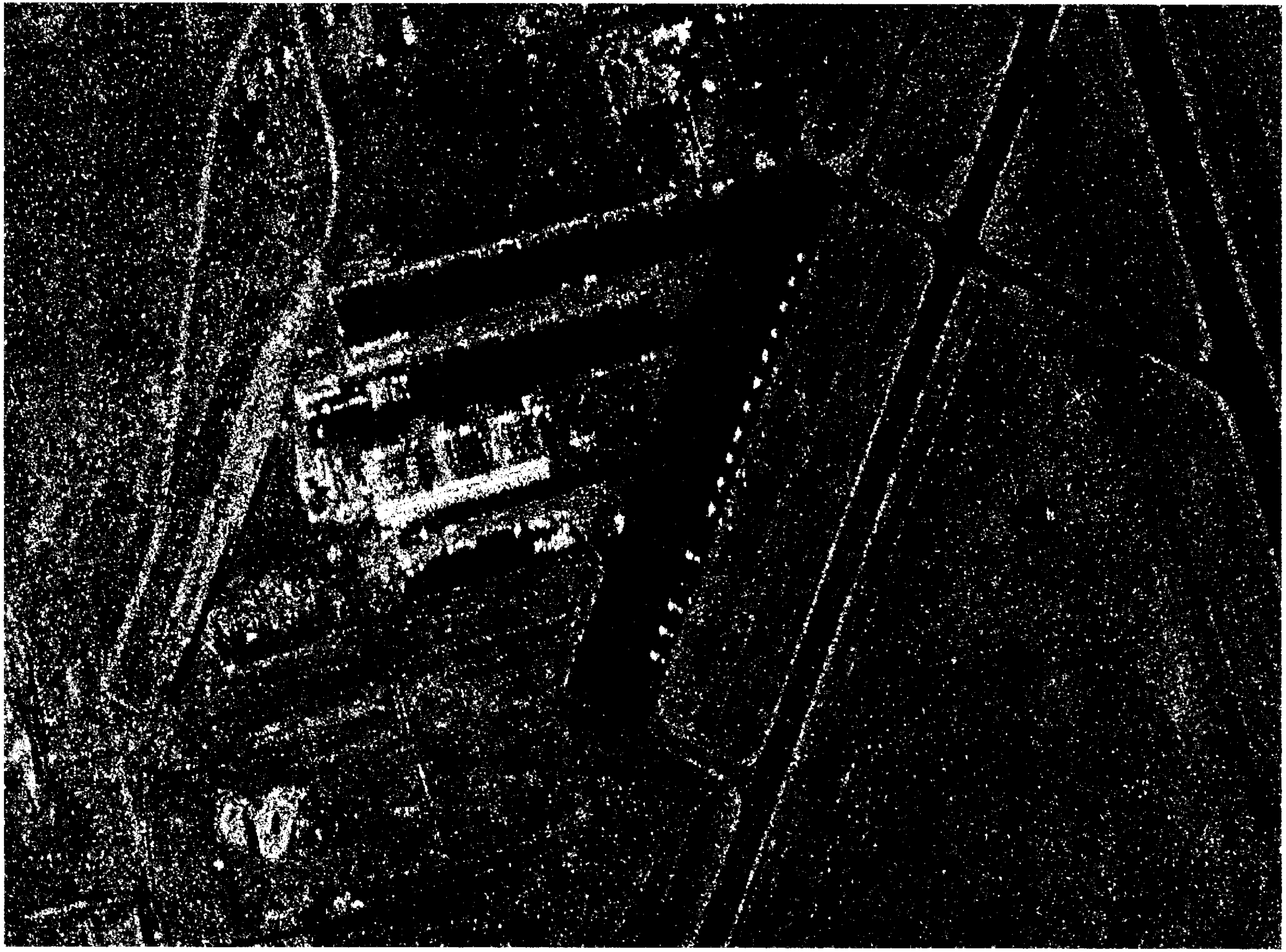
Range Spectra

First Topographic Elevation Data
X-band 80 MHz Right Looking



Color represents elevation with each color cycle corresponding to 300 m of elevation change.

X-band 160 MHz Bandwidth Image



Frequency Choice Rationale

- GeoSAR P-band radar operates at a center frequency of 350 MHz and has a bandwidth of 160 MHz. This range of frequencies covers frequencies allocated to FAA and others. Why does GeoSAR need to operate in this band?
  - Choice of frequency and bandwidth are dictated by the laws of physics and the constraint to fly on a commercially viable platform.
    - Center frequency was chosen to meet two criteria 1) have the highest frequency possible where good foliage penetration has been demonstrated 2) have a interferometric baseline that will fit on a Gulfstream aircraft and have good height accuracy mapping capability.
    - Bandwidth is dictated by the need to have a high resolution mapping system, 160 MHz provides .85 m of range resolution that after multi-looking gives the desired 5-10 m map postings.

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Need for Expanded Formulation of NTIA Interference Computations

- The advent of wideband radar applications was not anticipated when the original NTIA interference formulas were generated in 1972. Since then there has been a tremendous increase in applications operating at UHF frequencies and higher and that require large bandwidths.
- Experimental data taken by the FAA and JPL showed that the actual interference level was 40 dB lower than that estimated from the NTIA formula.
- Verified the notching capability of the GeoSAR radar to reduce interference.
- We propose a extended version of the NTIA analysis that better predicts the observed interference levels and that may be easily applied to proposed systems.

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Proposed Expanded Formulation of NTIA Interference Computations

- The major reasons the NTIA model over estimates the amount of interference generated by the P-band radar is the assumption of an ideal band pass filter which does not model victim receiver transfer function for the GeoSAR waveform very well. A more realistic model that takes into account
  - the pulsed nature of the GeoSAR waveform
  - the small time duration the interfering signal is in the pass band of the victim receiver (nano to pico-seconds)

  predicts the amount of interference level to within 10 dB.
- We have documented our theoretical analysis and our experimental data and have are submiting them to the NTIA.
- Working with FAA and others to conduct a test of the amount of interference generated by the P-band radar at Edwards Airforce Base.